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THE EFFECT OF FOOD INTAKE ON PERFORMANCE

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Introduction

Both mental and physical performance can be affected primarily by the extent to which the content of the food consumed meets bodily requirements and secondarily by the quantities of food consumed at each meal and the intervals between meals.

Accurate measurements of physical performance can be made by determining the work performed in a laboratory, under carefully controlled conditions, using standard equipment such as a bicycle ergometer. Such conditions, however, have little resemblance to those which exist on the athletic field or during an industrial operation. Consequently, the extrapolation of the experimental results into these situations, particularly the latter, is very difficult and hazardous.

The need for properly controlled investigations on the effect of food on industrial output was emphasized more than a decade ago by a cooperative committee appointed by the Council on Foods and Nutrition and the Council on Industrial Health (1) but little has been done since, although the need is almost as urgent now as it was then. Unfortunately, it is difficult to control conditions outside the laboratory and, even if laboratory conditions can be transferred to everyday events, an artificial situation is at once created.

Brozek and Monke (2) have recommended that the technique of "work miniature" situations be used in studies on nutrition and work performance. This technique is an attempt to bridge the gap between abstract laboratory studies and those in industry. It has been used in the evaluation of occupational fitness, industrial training, reciprocal machine adaption and the effects of physical environment. If applied to the subject under review it could, no doubt, assist in filling in many of the gaps that now exist in our knowledge of the effect of food intake on physical performance.

Food Requirements

Several countries have prepared dietary standards for guidance in the feeding of people engaged in various types of physical activity. The best

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known standards are probably those prepared by the Food and Nutrition Board of the National Research Council (3) although widely used tables have also been prepared by the Canadian Council on Nutrition (4) and, more recently, by the Committee on Nutrition of the British Medical Association (5). All these standards divide people into groups according to the type of activity in which they are engaged. For instance, the Food and Nutrition Board of the National Research Council divides men and women into three groups and recommends that the caloric and protein intake of each group should be as shown in Table I.

Table I — RECOMMENDED DAILY ALLOWANCES

	Calories	Protein
Man (154 lb.)		
Sedentary	2400	70 gms.
Physically active	3000	70 gms.
With heavy work	4500	70 gms.
Woman (123 lb.)		
Sedentary	2000	60 gms.
Moderately active	2400	60 gms.
Very active	3000	60 gms.

The American, Canadian and English standards are all, of necessity, based on essentially the same experimental evidence which tends to be fragmentary and inadequate. Consequently, the basic figures in each case are fundamentally similar, although there are many small differences, due largely to varying opinions in the interpretation of the available data. Furthermore, the tables were designed for slightly different purposes and, because of this, cannot be compared directly. Only the Canadian table is adjusted for body weight but all are intended for healthy people engaged in normal everyday activity. Unfortunately, tables frequently confer a false air of precision and dogma which, in this instance, is not only in error but could lead to misuse. This has been emphasized by Pett (6) in a comparison of the three standards.

In determining the activity group to which a person belongs, it should be remembered that the actual time during which a worker is engaged in the work for which he is employed is only about 20 per cent of the total number of hours in a week, also that about 30 per cent of his total time is spent sleeping, thus leaving about 60 per cent as leisure time to be spent as the individual thinks best. Hence, the average worker's leisure time forms a very substantial part of the total. Because of this, a clerical worker whose leisure is spent gardening, cutting firewood, cleaning windows or in similar activities may actually require a greater number of calories than a worker engaged in heavy manual labor who spends much of his leisure time playing

cards, listening to the radio or watching television. Furthermore, there is a tendency for those employed in heavy manual work to indulge in sedentary types of activity during their leisure time, whereas those employed in a sedentary type of occupation have a tendency to participate in physically strenuous pastimes during the evenings and week-ends.

This adjustment of activity does not take place with all people, a notable exception being the housewife whose work is fairly routine throughout the day and evening, generally for seven days a week. Her job of preparing meals and taking care of the home is frequently more strenuous than the work that many factory workers are expected to accomplish, and consequently more energy in the form of food may be needed. The introduction of labor saving devices has reduced the amount of manual effort required in some homes. Nevertheless, for the work the average housewife is required to perform, substantial amounts of food are still required, and it is deplorable that many, who are not required to prepare a mid-day meal for the rest of the family, will not go to the trouble of doing so for themselves.

Direct determinations of caloric needs for various kinds of work under normal conditions are comparatively few. Two of the most recent contributions in this field are those by Kraut et al (7) and Lehman et al (8). The former estimated that the daily energy requirements for 25 occupations in the steel industry, for conditions under which the output would equal the pre-war norm, ranged from 2950 to 4460 Calories. The latter in an attempt to determine the deterioration in work output resulting from different levels of caloric feeding, developed prediction tables for individual workers engaged in occupations ranging from "light" to "very hard" in which daily energy requirements ranged from 2,400 to 4,200 Calories. Both these sets of figures are in agreement with figures in Table I.

It will be seen from Table I that the recommended daily allowances of protein are the same for all activity groups. This is in agreement with the results of an investigation by Darling et al (9) using twenty-four young men as subjects. The men were engaged in various activities which ranged from truck driving, road mending and forestry to kitchen, laundry and office work. During the experiment, they continued their usual activities and, after a period of two weeks on normal diets, were divided into three groups, one receiving a low protein diet, another a high protein diet and the third remaining as the control. At regular intervals the men were tested for physical fitness, but at the end of the experiment no significant difference could be found. More severe conditions have been investigated by Kraut and Lehman (10) who conducted a 7½ months study using three Hungarian coal miners. For heavy work the amounts of protein required were found to be much the same as for light work, but when the protein intake was reduced, work

capacity began to fall off and the subjects became depressed and uncooperative. This attitude disappeared when the protein intake was again raised and, after a latent period, work capacity rapidly improved.

Hence, there is no evidence that additional quantities of protein are required for moderate, muscular work. It is known that after muscular work urinary nitrogen increases but the increase is not great and cannot be correlated with the amount of work performed (Wilson, 11). If the work is particularly strenuous additional protein may be taken. It is interesting to note that athletes, whose total energy requirements are large, frequently prefer protein foods to those containing large quantities of readily available carbohydrate. Protein foods cause smaller fluctuations in blood sugar levels (Conn and Newburgh, 12) with less likelihood of hypoglycemia.

In caloric inadequacy, proteins are used inefficiently as a source of calories, while in diets supplying an adequate level of calories, proteins can then serve their more useful function in the growth and repair of tissues, and to replenish protein stores.

There is not much information concerning the human requirements for fat and the amounts provided are usually based more on food habits than physiological requirements. The Food and Nutrition Board of the National Research Council (3) recommends that, for a person of average activity, fat should be included in the diet to the extent of at least 20 to 25 per cent of the total calories and, for a very active person whose caloric needs are in the vicinity of 4,500 Calories, to the extent of at least 30 to 35 per cent. Since fat confers compactness to the diet it may be consumed in increased quantities thus allowing the proper number of calories to be supplied without too much bulk. If the quantity of fat in the diet is excessive, however, other physiological problems of digestion are encountered.

For strenuous visual work, the results of Simonson et al (13) indicate that either a balanced, or a high fat, meal is preferable. In a type of strenuous visual work which required the recognition of fine detail on a moving conveyor belt, Simonson et al compared three types of meals (balanced, high fat, high carbohydrate) using six subjects. The deterioration of work performance was most marked after the carbohydrate meal and least marked after the balanced meal. An interesting conclusion from this study was that it appeared impossible to improve, by any type of meal, all the functions involved in such a complex performance as strenuous visual work.

During the initial stages of work, carbohydrate is utilized to a larger extent than fat. Simonson (14) attributes this to faster mobilization. In four series of experiments on six subjects, living on a diet poor in protein, Krogh and Lindhard (15) found that work is more economically performed on carbohydrate than fat. Marsh and Murlin (16) reported the results of an

experiment on the muscular efficiency of a single subject on a normal diet, a high-carbohydrate diet and a high-fat diet. For work at two different levels, the average net efficiency was higher on the high-carbohydrate than on the high-fat diet. In more recent years, Christensen and Hansen (17) have published metabolic data for three trained subjects on normal, high-carbohydrate and high-fat diets. When carried to exhaustion, the possible duration of work on the high-carbohydrate diet was 2 to 3 times as great as on the high-fat diet. In further experiments, it was found that the consumption of sugar, either before or during work, prolonged the possible duration of the work but no explanation could be given (Christensen and Hansen, 18).

Mitchell and Edman (19) favor the ingestion of high carbohydrate meals before and during air travel for the reason that they increase "mental efficiency," neuromuscular coordination, the capacity for muscular work and the acuity of vision in a dim light.

Claims have been made that the consumption of supplementary quantities of gelatin, glycine, several phosphates and various vitamins have a favorable effect on physical performance, and that the vitamin, thiamine, will improve mental performance. Most of the experiments on which these claims are based have not been properly designed nor sufficiently controlled. The literature has been reviewed in Nutrition Reviews (20) and from this review, and the small amount of literature that has appeared since, there seems little reason to believe that, for a person on an adequate well-balanced diet, performance can be improved by the supplementary ingestion of any specific food constituent. Under certain extreme conditions, however, additional supplies of some vitamins, and sodium chloride, may be required.

It has been stated by Bicknell and Prescott (21) that the thiamine requirements of an individual may be increased fifteen times in severe exercise and Bourne (22) has pointed out that to obtain this requirement by the consumption of natural foods one would need to consume 6.5 kgm. of wheatmeal bread or nearly twice this amount of lean meat. It is most unlikely, therefore, that an athlete could fulfill his requirements of thiamine by the consumption of natural foods. Furthermore, a similar position may exist with regard to other vitamins such as riboflavin, nicotinic acid and ascorbic acid. The question therefore arises as to whether strenuous physical exercise can be limited by vitamin intake and, if so, whether it can be improved by the administration of vitamin supplements. Bourne, after reviewing the literature, is of the opinion that it can, but deplores the fact that so little work has been done in this field.

Most people do not require more sodium chloride than that which normally occurs in the diet. In fact, in hypertension salt intake is often sharply restricted. When sweating is excessive, however, large quantities of sodium

chloride may be lost in the sweat and unless the sodium chloride in the blood is prevented from reaching low levels, heat cramp is likely to develop. To prevent this, it is recommended (Food and Nutrition Board, National Research Council, 3) that an additional one gram of sodium chloride be consumed for each liter of water taken in excess of four liters daily.

Work and Efficiency

Physical work may be defined by the equation:

$$W = L \times D$$

where W represents work, L the load lifted and D the distance through which it is lifted. Since work is the product of weight units and distance, it may be expressed as kilogram-meters or, since all forms of energy are interconvertible, as Calories, one Calorie being equal to 426.5 kilogram-meters. Gross physical efficiency may be defined by the equation,

$$E = \frac{100\ W}{H}$$

where E represents gross physical efficiency, H the total energy required and W work, as before. To obtain net physical efficiency, the energy required for rest is subtracted from the total energy required. In this review, only net efficiencies will be considered and, as thus defined, these are expressed as a percentage. The human body is considered to be efficient when it performs work at low energy cost and inefficient when the energy cost is high. A number of experiments have been conducted to determine whether the ingestion of food is followed by an increase in efficiency and some of the most important of such studies will be discussed.

In 1931, Carpenter and Fox (23) conducted experiments to determine physical efficiencies when there had been no ingestion of sugar, and after 50 gms of each of two sugars, glucose and fructose, had been taken. The subject performed one hour's work at 275 kgm-meters per minute and half an hour's work at 555 kgm-meters per minute. Average efficiencies were much the same when there had been no ingestion of sugar and after the ingestion of glucose or fructose. Hence it was concluded that neither the ingestion of glucose or fructose resulted in an appreciable increase in physical efficiency. Several years later, Carpenter and Lee (24) determined physical efficiencies after the ingestion of two other sugars, sucrose and galactose, the amount of the first being increased to 70 gms. After sucrose, the subject performed half an hour's work at 550 kgm-meters per minute and after both sucrose and galactose, one hour's work at 275 kgm-meters per minute. Again there was no significant difference between efficiencies and it was concluded that neither sucrose nor galactose increase physical efficiency appreciably.

While the above work was proceeding, Haggard and Greenberg (25) published the results of a typical experiment in which physical efficiencies were determined at hourly intervals throughout the day. The lowest efficiency was found just before breakfast and the highest one hour after breakfast, the efficiency rising from 19.5 to 27.0 per cent in one and a half hours. Later it fell, until at noon, it was only 21.2 per cent which was only slightly higher than the pre-breakfast figure. Lunch was consumed between 12:15 and 12:30 p.m. and by 1:00 p.m. the efficiency had risen to 26.0 per cent and by 2 p.m. to 26.3 per cent. It then steadily declined until at 6:00 p.m. it was 20.8 per cent which was again only slightly higher than the pre-breakfast figure. Although these results were for only one subject, similar results were obtained in ten further experiments using four subjects. The results of these experiments are not in agreement with those by Carpenter and his colleagues and indicate a definite rise in physical efficiency following the ingestion of food.

Using two subjects, Haldi et al (26) determined physical efficiencies after the ingestion of 50 gms of glucose, fructose, a mixture of both these sugars, and water. Work was performed for two consecutive fifteen minute periods at the rate of 550 kgm-meters per minute. Physical efficiencies after each sugar and the mixture were found to be the same as that after the ingestion of water alone. Further experiments were conducted in which exercise was taken (a) 30 minutes after the ingestion of 20 gms of glucose, fructose, a mixture of both and water; (b) in the fasting state and one, two and three hours after the ingestion of a 50 gm mixture of glucose and fructose and; (c) before, one, two and three hours after breakfast. Exercise was for thirty minutes in the first series and fifteen in the second and third, the rate being 550 kgm-meters per minute. When 20 gms of sugar was ingested, the efficiency was almost the same as when water alone was taken. In the fasting state and after the ingestion of the 50 gm mixture, the efficiency remained almost the same. Before, one, two and three hours after breakfast, the efficiency remained practically constant. The efficiency also remained unchanged over the same length of time in experiments in which no food was taken. Furthermore, it was unchanged one hour after a high carbohydrate breakfast. Hence, it would appear from these results, that physical efficiency is not improved by the taking of food.

The results of the preceding experiments lean heavily towards a conclusion that the taking of food is not followed by an appreciable increase in physical efficiency and more recent experiments by Wrightington (27), during which the sugars sucrose and glucose were fed, support this conclusion. In these latter experiments, there was a slight rise in efficiency after both sugars but it was not significant. However the fact that the ingestion of food is not followed by an increase in physical efficiency does not mean that the

taking of food has no effect whatsoever on athletics or work performance. Later it will be shown that other factors associated with the consumption of food can be responsible for an immediate and substantial effect on performance.

Experiments on the effect of food consumption on mental work and efficiency are comparatively few, due no doubt, to the looseness with which these terms are used and to the difficulty in defining and measuring their various components.

The energy requirements for unemotional mental work are small, and for a simple mental calculation are probably not much greater than 3 or 4 per cent of the requirements for a simple state of attention (Benedict and Benedict, 28). By neglecting energy requirements for this kind of mental work, therefore, a serious error is not introduced into a calculation of physical work or efficiency. On the other hand, it has been demonstrated (Shaw, 29) that thinking may be associated with incipient speech movements, or mental images, recorded in terms of muscular tensions and that the energy required to produce these tensions may be large in comparison with that required for thinking alone.

Eiff and Gopfert (30) conducted studies on twelve students who counted, learned a poem, or otherwise exercised their minds on prescribed tasks while reclining in the most comfortable position possible. Muscle action currents and mechanical impulses were registered and energy output measured. In fifty-seven experiments there was an average rise of 11.6 per cent above resting metabolism measured at the same session. The variation was wide, in forty-nine there were increases from 1 to 56 per cent, in one there was no change, and in seven there were decreases from 4 to 21 per cent. The extent of the change was thought to be due to eagerness to learn, as well as emotional factors.

In order to investigate whether there is a difference in ability to concentrate between people with empty stomachs, and after the ingestion of small quantities of food, Hutchinson (31) conducted several experiments using people engaged on various kinds of office work as subjects. In one experiment 38 subjects were given two tests each lasting 1.5 minutes. The first consisted in placing a symbol against individual numbers, of which there were several rows, according to a given key; the second consisted of crossing out six figure numbers, of which there were several columns, containing certain specified pairs of figures. From this experiment it was found that better results were obtained by those subjects who first consumed a simple light refreshment consisting of sandwiches and tea, the difference for one of the tests being significant at the 1 per cent level.

In a further experiment, 88 people served as subjects. On this occasion

only one test, lasting 3.0 minutes, was given and this required each subject to work through rows of six figure numbers, placing a check against each number that contained 2 and 4 and a cross against each number containing 6 and 9. From the results of this experiment it was again found that better results were obtained by those subjects who first consumed a simple light refreshment consisting of sandwiches and fruit cordial, the difference also being significant at the 1 per cent level.

Differences in mental efficiency following the consumption of heavy and light meals of unspecified size have been investigated by Laird et al (32), and differences in physical and mental efficiency following the consumption of two light meals and a divided meal have been determined by Hovland (33). As different efficiencies were measured in each investigation, the results of these tests, and those conducted by Hutchinson, are not comparable.

Athletic and Industrial Performance

Athletics and industrial performance involve activities of many kinds, both physical and mental, which may be carried out under a great variety of environmental conditions, each introducing its own particular problems. Attempts have been made to analyze these activities under headings such as strength, speed or endurance, but the matter is far too complex for such simple treatment. Many experiments have been conducted to determine the effect of food on various types of performance under normal conditions but, under such conditions, rigid control becomes impossible and unless the experimental conditions can be varied in such a way that the proper evaluation of all responsible factors is possible, the results are of limited value. In the following investigations conducted in the industrial or athletic field, care has been taken to eliminate as many extraneous factors as possible. Nevertheless, the results must be interpreted with reservation.

In 1935, Haggard and Greenberg (25) conducted experiments in a large rubber footwear factory to determine the effect of food intake on performance as measured by work production. Forty operators divided into two groups of twenty each served as subjects. In one group, the control, the operators ate their accustomed three meals a day and, in the other, they ate three, five, three, five, three meals respectively, for periods of two weeks. The mean hourly output of the operators in the control group was 183, 184, 183, 184 and 184 for each period of two weeks. The mean hourly output of the operators in the experimental group during the three period in which they ate three meals a day was 175, 176 and 176 and during the two periods in which they ate five meals a day 192 and 194. From these results, Haggard and Greenberg came to the conclusion that the extra meals increased daily work productivity.

In earlier experiments by Haggard and Greenberg, it was found that operators who omitted breakfast showed a low rate of morning work production. Similar results have been obtained by Tuttle, et al (34), Daum et al (35), Tuttle et al (36) and Tuttle et al (37) who found also that the provision of coffee did not remedy the defect but that a light breakfast caused a slight improvement. In fact it has been concluded from this series of experiments that breakfast is essential for maximum performance, both physical and mental, during the morning hours; that omitting breakfast results in detrimental effects which can be reflected in decreased work output and mental acuity, and that a breakfast supplying 25 per cent of the daily caloric needs permits, in most cases, a greater work output than a breakfast supplying 40 per cent of the day's calories.

In 1927, at the Hawthorne Works of the Western Electric Company, Chicago, arrangements were made to isolate for observation a group of five women assembling telephone relays. For a period of seven months, the women were allowed varying morning and afternoon rest pauses during one of which food was provided. The rest pauses were two of five minutes, one in the morning and one in the afternoon for five weeks; two of ten minutes, one in the morning and one in the afternoon for four weeks; six of five minutes, three in the morning and three in the afternoon, for four weeks; and one of fifteen minutes in the morning during which a light meal was served, and one of ten minutes in the afternoon during which no food was provided, the last arrangement lasting eleven weeks. Accurate production records were kept and from these it was seen that the introduction of rest pauses without food resulted in a definite increase in production, but that the increase was only slightly greater after a rest pause during which food was consumed. This suggests that the consumption of food was of less value than other conditions associated with the rest pause. The average hourly outputs for each subject are presented graphically by Roethlisberger and Dickson (38).

Haldi and Wynn (39, 40) conducted experiments to determine how the rate of production is affected by different amounts of food consumed during the mid-morning or mid-afternoon rest pauses. The tests were conducted in a large cotton-bag factory using as subjects thirty-two women engaged on the sewing of bags on electrically driven sewing machines. An hourly count of the numbers of each kind of bag sewed by each subject was made. Results were then expressed in terms of standard hourly production. For three consecutive weeks the refreshments supplied on different days were as follows: (1) frankfurt sausage, potato chips, bun, soft drink = 650 Cal.; (2) cake, banana, milk = 300 Cal.; (3) milk chocolate = 150 Cal.: (4) soft drink

= 80 Cal. The order of serving the refreshments on successive days was different each week. During the mornings, the average hourly production before and after each kind of snack was, (1) 123 and 138; (2) 123 and 136; (3) 124 and 133; (4) 122 and 134. During the afternoons it was: (1) 125 and 135, (2) 122 and 131, (3) 123 and 125, and (4) 123 and 133. From the results it is evident that work output increased slightly after the mid-morning and mid-afternoon rest pauses but the rise was not related to the kind or amount of food eaten. Furthermore, abstention from food during the rest pauses on two days of the experiment did not impair work production.

The results of these investigations on work performance are contradictory but they do not rule out the possibility that morning and afternoon snacks may increase industrial productivity. Clearer results might have been obtained if the processes studied had required greater physical effort. Nevertheless, it seems unlikely that the increase is as great as that resulting from other conditions associated with the rest pause. Psychological as well as physiological aspects need consideration and it may be that the accompanying break is psychologically more important than the food consumed.

In the athletic field, Haldi and Wynn (41) studied the performance of twelve healthy young swimmers in a one hundred yards sprint 2½ to 3 hours after a heavy meal of 1051 Cal., and a light meal of 551 Cal., and after a light meal supplemented with 50 and 100 gms of sucrose immediately before swimming. After each meal, the time taken to swim one hundred yards was the same. The results provide evidence, therefore, that there is no relation between the speed in swimming one hundred yards and the taking of food immediately before, or 2½ to 3 hours before, swimming.

Actually there is a dearth of scientific information on the most desirable kind of meal that should immediately precede an athletic event. Severe exercise alone appears to have little effect on digestion but the strong emotions which accompany competition in even the milder kinds of sport may retard digestion and impede high level performance. For these reasons, some coaches prefer athletes to eat 3 to 4 hours before the event. They also believe that the meal should consist of easily digested foods which, at the same time, will also furnish the energy necessary for the particular sport.

Clarke et al (42) studies a group of about 150 Indian schoolgirls in Johannesburg during the Ramadan festival and three weeks after its conclusion. During the festival, the ordinary daily feeding routine of three meals is reduced to two. The first meal is taken very early in the morning and no food is consumed throughout the day, but a large supper is served in the evening. This reduction in the number of meals had a significantly unfavorable effect on the 100 and 600 yards running performances. In the 600 yards race, it affected the younger children most. In putting the shot, a significant de-

terioration was noticeable in the older girls only. A study of body weights showed that the reduction in the number of meals had caused a significant loss.

None of the preceding experiments provides conclusive evidence that the consumption of food is followed by any very marked improvement in industrial output or athletic performance. On the other hand, the favorable effect of sugar intake on fatigue after prolonged exhaustive exercise such as running a Marathon race seems to be well established (Christensen and Hansen, 43). It is probable that the slight improvements noted in the experiments on industrial output, were due partly to psychological effects associated with the period during which food was taken. If so, they are not inconsistent with the results of Haldi and Wynn on athletic performance. In the study by Clarke et al the fact that the reduction in number of meals caused a significant loss of body weight suggest, that with only two meals, the subjects were taking insufficient food for their daily requirements.

It should not be forgotten, however, that diet is also an environmental factor whose influence is felt only after considerable exposure. Therefore, it may not be reasonable to expect significant data from experiments involving a new set of conditions that have been in operation for a comparatively short time. Hence, the significance of some of the results may have vanished had the changed conditions been in operation for a much longer period.

Intervals Between Food Intake

By the fractional method of gastric analysis, Killian and Marsh (44) determined gastric evacuation times for a variety of solid foods consumed with water. Using standard farina test meals, Van Liere et al (45) investigated fluoroscopically the relation between the quantity of food ingested and the emptying time of the stomach. From the results of these investigations it would appear that an ordinary mixed meal should leave the stomach in three to four hours, although the authors have found individual variations in emptying time to be considerable.

When the stomach is nearly empty, hunger contractions set in. At first the contractions are comparatively feeble; later they become stronger, particularly in young children. In a young child they may cause considerable discomfort and actual pain. In an older child, or adult, although not sufficient to cause pain they may be associated with a feeling of weakness and emptiness, slight headache and sometimes nausea. There may also be increased excitability of the central nervous system as shown by restlessness, irritability and diminished concentration and attention. These conditions have been described by Carlson (46) and more recently by Stavel (47). Carlson terms the symptoms "accessory hunger phenomena" because they are not always

present in hunger, and because their relative preponderance depends on the length of time since food was last consumed and on individual differences. In some people these accessory hunger phenomena appear to overshadow, if not entirely suppress, the hunger pain sensations from the stomach.

Sangster et al (48) investigated the assumption that the faster the stomach empties, the earlier hunger contractions occur. They used a test meal of cooked cereal paste which could be liquified with malt amylase to hasten evacuation. The amylase itself did not effect evacuation but altered the consistency of the meal without greatly altering its carbohydrate content. The liquified and non-liquified meals were given to two men on alternate days and the subsequent onset of hunger contractions was recorded. The onset after the liquified meal was found to be significantly earlier in one subject and earlier, but not significantly so, in the other. It would appear, therefore, that hunger contractions occur most quickly after those meals that take least time to leave the stomach.

Laird et al (49) conducted a large scale experiment, using 53 nervous children to determine whether hunger contractions resulting from a long period between meals, and also lack of calcium, can be responsible for nervousness. The children were divided into three groups and at 9:30 a.m. each morning one group played with toys, the second received half a pint of milk and the third half a pint of milk containing a food concentrate. The milk was provided to delay the onset of hunger contractions and the milk plus concentrate to delay hunger contractions as well as providing additional calcium. At the end of two weeks, the group that played with toys showed a slight decrease in nervousness which was attributed to the improvement that frequently occurs when a nervous child is given special attention. The group receiving milk only, showed a much greater improvement and the group receiving milk plus concentrate nearly twice the improvement shown by the group on milk alone. Hence it was concluded that a special meal of milk between the first two meals of the day postponed hunger contractions with a consequent reduction in nervousness.

Another investigation along the lines of that just described has been conducted more recently by Keister (50). In this investigation water and unsweetened pineapple juice were served at 10:00 a.m. each morning to 133 nursery school children divided into four groups. The study extended over four quarters of the year, and in each quarter, two of the groups, one older and one younger, received pineapple juice and the other two water. In the following quarter, the treatments were reversed. The children taking pineapple juice consumed from 4 to 8 ounces daily but those taking water rarely consumed more than 3 ounces. From the results of this experiment it was concluded that, in most instances, the consumption of pineapple juice reduced

irritability and tension, and promoted a feeling of satisfaction and well-being during the remaining hours of the morning. This improvement was no doubt partly due to the postponement of hunger contractions, although as in the previous experiment, the provision of additional nutriment may have had some effect. In both experiments, definite information on the nutritional status of the children was not given. Consequently the results are not conclusive.

Although the results of the preceding experiments using children as subjects must be accepted with reservation, they provide some evidence that long periods between meals result in nervousness, irritability and tension which can be improved by shortening the periods between the consumption of food. Evidence in which adults have been used as subjects is not available, but the effect of long periods between meals on ability for mental concentration has been investigated by Hutchinson (31).

In the first experiment, to which brief reference has already been made, 69 officials engaged on various kinds of office work in a large government department, served as subjects. These officials were divided into four groups, two of which participated in experiments in the late hours of the morning when no food had been consumed for at least four hours and the stomachs of most of the subjects could be assumed to be practically empty, and the other two in the late hours of the afternoon when no food had been consumed for at least two and a half hours and the stomachs of more than half the subjects could be assumed to be practically empty. Each part of the experiment covered two consecutive days. On each of the first two days, two groups left their desks at 11:50 a.m. and 3:30 p.m. respectively, and quietly transferred to another office where they were given two sandwiches weighing 5 ounces and 9 ounces of hot tea. At 12:10 p.m. and 4:10 p.m., respectively, the other two groups took up places at desks in the same office and, without delay, two pencil and paper tests, as described earlier, were administered. On the following day, the same procedure was followed but the groups were reversed so that those subjects that did not consume food before the tests on the first day did so on the second. The tests were marked, and the results analyzed statistically, when it was found that, for the first test administered in the morning, the effect of taking food before the test was an increase of score significant at the 1 per cent level; for the second test there was no significant effect. For neither of the tests administered in the afternoon, was the effect of taking food before the test significant. This was expected for most of the subjects had had lunch less than three hours earlier and few would be experiencing the onset of hunger contractions.

In the second experiment (Hutchinson 31), 88 government officials served as subjects and, as the experiment was conducted in the late hours of

the morning, and not in both the morning and afternoon as before, the subjects were divided into two groups. Also, only one test was given, and this covered a period of three minutes being a combination of the two earlier tests. It required each subject to work through rows of six figure numbers, placing a check against each number that contained 2 and 4 and a cross against each number that contained 6 and 9. There was also an alteration in the food provided, the tea being replaced by 7 ounces of fruit cordial. The test sheets were marked and on analyzing the results as before, it was found that the effect of taking food before the test resulted in an increase in score significant at the 1 per cent level. Hence it was concluded that, under the conditions of the test, ability to concentrate at a time when the stomach can reasonably be assumed to be empty is improved by the consumption of small amounts of food. Possibly there is a distinction between work requiring various degrees of concentration, particularly if concentration covers only a short period.

Other experiments, in which women served as subjects, are also worth reviewing. Although unsatisfactory in some respects, they provide indirect evidence that long periods between meals may result in mental irritability, tension and diminished concentration.

In 1935, Comstock and Eddy (51) reported the results of two series of tests designed to determine the effect of supplementary feeding on the absence of women workers in an industrial plant. In the tests, groups of volunteers were given a supplementary snack of one banana plus half a pint of milk, or one banana alone, during each of two rest pauses daily. Groups without the supplement were chosen as controls. The results of the tests pointed to a definite reduction of absence through illness as a result of the supplementary feeding, the improvement being most marked in the group receiving bananas plus milk. In a similar study, Haggard and Greenberg (52) used as subjects one hundred and twenty women who were engaged in sorting and checking baggage slips and preparing monthly statements for customers. The study extended over seven months during which the women were divided into three groups which received in turn a supplementary snack of bananas, or bananas plus milk, each morning and afternoon. During the months when subjects received supplementary feeding they had, without exception, a lower rate of absenteeism than the group without a supplement and the subjects were generally of the opinion that they became less tired, were more cheerful and paid more attention to their work.

Hence it would appear from this discussion that periods between meals, particularly during the working day, should not exceed three or four hours. Direct evidence has been presented supporting this for those engaged in sedentary work, while Pyke (53) provides evidence in support of more fre-

quent meals for those doing heavy work. From experiments on the effect of heat on man, Schlegel and Bottner (54) concluded that small frequent meals should be taken during work periods and larger quantities of food, if required, when the work is finished. During an investigation on man's tolerance of intense cold, Mitchell et al (55) found that small meals spaced at short intervals were more favorable than large meals spaced at 4 to 6 hour intervals. Bierman (56) provides evidence in favor of small meals for aviators. It is seen, therefore, that for heavy and light work, in cold and hot environments, and at high altitudes, there is evidence in support of shorter periods between meals. If the periods between meals are reduced, however, it is important that the amount of food consumed at each meal be also reduced.

Limitation on Size of Meal

Following the consumption of a large meal, there is usually a feeling of drowsiness, lack of coordination and a disinclination for mental or physical activity. In factories and offices where employers have a full mid-day meal and their hourly production rate can be measured, the effect is shown on the production curve by a characteristic flattening for the first hour or so after the mid-day meal (Hutchinson 57).

Many theories have been advanced to account for the lassitude, lack of coordination and disinclination for work experienced after a heavy meal. The explanation advanced by Laird et al (32), and to which there are frequent references in the literature, is that there is a temporary "brain anemia" due to the heavy demands of the digestive organs for blood. This explanation is supported by the work of Pearcy and Allen (58) who found that distention of the stomach with air produces effects similar to those which arise from eating a large meal. Another possible explanation could be that the ingestion of a heavy meal produces mild post-prandial hypoglycemia. When is a heavy meal is consumed, the blood sugar rises sharply. If the rise is sufficiently sharp, insulin may be overproduced, reducing the blood sugar to a lower level than before and causing mild hypoglycemia.

Hutchinson (31) has conducted experiments to determine the size beyond which a meal should not extend if post-prandial lassitude, with its resultant effect on mental concentration, is to be prevented. The test consisted in typing from standard sheets, while exchanging certain pairs of letters, a task which required no particular ability or skill but fairly intense concentration. This test, lasting 15 minutes, was given immediately after the subjects had consumed meals, the solid portions of which varied from 6 to 18 ozs. From the results it was found that the effect of size of meal on number of words typed was highly significant, the typists working best after meals, the solid portions

of which weighed 9 to 12 ozs. However, in further tests it was found that the effect of size of meal could be rendered insignificant if motivation to do well were sufficiently great.

Laird et al (32) investigated the extent to which mental performances are reduced after a heavy mid-day meal. They conducted experiments using young men accustomed to varying types of mental work. For periods of six days during four consecutive weeks, the men ate their mid-day meals in the laboratory; on half the days they had heavy meals and on the remaining days light meals. During the hour following lunch, tests were made to estimate relative values for memory of new addresses, speed and accuracy of addition, speed of controlled association, fluctuation of attention, shift of sensory acuity and feelings of fatigue. In each test, the results were better after the light meal, and it was estimated that an increase in mental accuracy of about 25 per cent occurred, and that lapses in attention were nearly 70 per cent fewer. Unfortunately, there is no information concerning the actual size of each meal.

In addition to their effect on mental performance, large meals are physically inconvenient for those who subsequently engage in physical exercise or work in a crouched posture. No experiments designed to determine the maximum size for a meal, that will not retard physical performance, have been recorded. Pyke (53) has pointed out that small meals are especially convenient for coal miners because of their high energy requirements, and need for meals not too bulky to hamper movement in a crouching position. Hutchinson has pointed out that for the same reason sheep shearers prefer a small mid-day meal and there are many athletic performances, such as rowing, in which small meals could be a distinct advantage.

Summary and Conclusions

(a) The occupation at which a person earns his living may be a poor indication of his nutritional requirements, and in calculating such requirements, should never be considered apart from the manner in which he spends his leisure.

(b) If the diet is adequate with respect to fats and carbohydrate, these constituents will provide most of the calories, the quantities supplied by each depending more on their consumption due to habit than on physiological requirements.

(c) Under normal living conditions, the provision of supplementary foods is probably not necessary, but if exhausting physical exercise is performed, additional thiamine and possibly other vitamins, as well as sodium chloride, may be required.

(d) There is strong evidence that the nutriment provided by the consumption of food does not, in general, cause an increase in physical efficiency, although the consumption of sugar has beneficial effects after extreme exertion.

(e) There is some evidence that certain mental efficiencies, such as concentration, may be improved by the consumption of small quantities of food when the stomach is empty and hunger contractions have set in.

(f) There is little doubt that morning and afternoon rest pauses during which food is consumed increase industrial productivity, but it is not clear to what extent psychological factors are responsible.

(g) The consumption of food immediately before an athletic event does not appear to improve performance and, because emotional factors can retard digestion, most coaches prefer athletes to eat 3 to 4 hours before the event.

(h) There is some evidence that long periods between meals result in nervousness, irritability and tension which can be improved by shortening the periods between meals with a compensating reduction in the size of the meals.

(i) To prevent the feeling of drowsiness, lack of coordination and disinclination for physical or mental activity following the consumption of a large mid-day meal, there is evidence that, for sedentary work, the size of this meal should not exceed 9 to 12 ozs.

(j) Large meals are physically inconvenient for manual workers who are required to work in a crouched posture but no attempts appear to have been made to measure the adverse effects of meal bulkiness.

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